

# Distributed Energy Transaction Mechanism Design Based on Smart Contract

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**Abstract**—With the promotion of power energy market reform, it has been a trend to allow distributed energy agents and other multi-subject agents to participate in the market competition. However, due to the existing power market mechanism is designed according to the centralized power supply mode, the public services, power market transaction mechanism and government management system for distributed energy transaction is still more missing. The blockchain technology has the characteristics of decentralization, transparency, fairness, openness and so on. Under the background of the transactive energy system, a decentralized distributed energy transaction mechanism based on blockchain smart contract technology is proposed, which includes auditing, bidding, clearing and settlement. It realizes P2P energy trading among prosumers.

**Index Terms**—Distributed energy transaction; prosumers; blockchain; smart contract; decentralization; transactive energy system.

## I. INTRODUCTION

With a large number of distributed power generation, distributed energy storage, electric vehicles, smart electrical equipment and other large-scale access to the power grid, users are also transformed from a single producer or consumer to a prosumer, the traditional power system is facing the new challenge. The concept of Transactive Energy came into being. Transactive Energy gives the distributed power unit a higher degree of autonomy. And the flexible and controllable power generation and load unit can suppress the uncertainty of the uncontrollable power unit to maintain the dynamic balance of system supply and demand. And it also has the characteristics of real-time, autonomous, and decentralization.

In the traditional energy and power industry, a method of centrally optimizing the allocation of resources is adopted. There is a large degree of information asymmetry between users and users, users and suppliers. With the advancement of the new round of power system reform, opening up the power-selling side market and allowing multiple entities such as

distributed power sources to participate in market competition has become the trend of China's power market development. In the distributed generation transaction, each producer has full control of its own power generation equipment and has strong uncertainty and difference in the characteristics of electricity generation and quotation; the self-interest of the prosumers makes it more demanding on fairness, privacy and non-discrimination. In this scenario, the traditional way of centralized bidding through the trading center is not only inefficient, but also unable to meet the requirements of the consumer, consumer, trust, fairness, and privacy.

This paper proposes to establish a decentralized distributed power generation market-oriented trading mechanism, which can enable users and suppliers to obtain market information, reduce the cost of information acquisition, and improve the efficiency of decentralized decision-making. The mechanism no longer needs the central decision-making body, the user and the user independently conduct transactions, there is no third-party interest relationship, solve the trust problem in the transaction, and ensure the fairness, transparency and non-discrimination of the transaction.

## II. DISTRIBUTED ENERGY TRANSACTIVE MECHANISM

### A. Transactive energy system for distributed agents

The GridWise Architecture Council proposed a definition of transactive energy in [1] as follows:

“A system of economic and control mechanisms that allows the dynamic balance of supply and demand across the entire electrical infrastructure using value as a key operational parameter.”

In the context of transactive energy, distributed energy is directly controlled by its owner; Prosumers participate in the market. Similar to the demand response mechanism, the research focus of transactive energy is how to design an effective incentive mechanism; But it is not only limited to the demand side, but also includes the supply side, and characterized by real - time, autonomy, decentralization [2].

Under the background of the transactive energy system, P2P

energy trading model among prosumers is proposed.

### B. P2P energy trading model

P2P energy trading is a novel paradigm of power system operation, where people can generate their energy from Renewable Energy Sources (RESs) in dwellings, offices and factories, and share it with each other locally. Generation of DERs is unpredictable and intermittent, and prosumers who have surplus energy can either store it with energy storage devices, or supply others who are in the energy deficit [3]. In this P2P trading mode, cash flow and power flow are shown in Fig. 1.

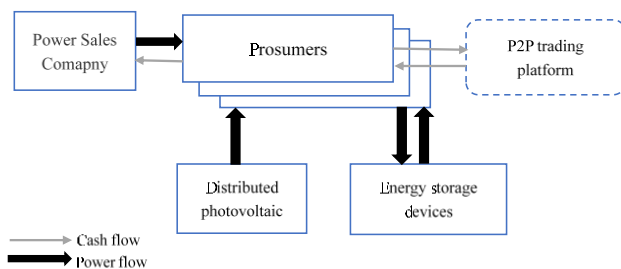


Fig. 1 Cash flow and power flow in P2P trading mode

There are already many literatures at home and abroad that introduce the P2P trading mechanism. In [4], a self-constructed electric energy trading method between producers and consumers who combines new energy generation, energy storage and P2P energy exchange in microgrid is proposed, and the P2P transaction mode is introduced. The literature [5] points out that blockchain technology the problem of trust in distributed energy trading is solved. The paper establishes a kind of intelligent contract to realize the unsupervised electric energy auction. The literature [6] evaluates the feasibility of P2P electric energy trading in the low-voltage distribution network, and proposes P2P. The energy trading index uses the k-means clustering method to cluster the historical data, classify the users according to the power consumption mode, and obtain the optimal capacity of different distributed energy sources through linear programming optimization, so that the local demand and supply balance are maximized. Literature [7] outlines distributed P2P energy trading, P2P network control and wireless communication solutions, and introduces the experimental results in the P2P SmartTest project, demonstrating the advantages of P2P mode when a large number of small-scale distributed energy is connected to the grid; Literature [8] defines a three-dimensional P2P energy trading system architecture, which is the time axis in P2P energy trading, the size of P2P energy trading users, P2P The four interoperability layers that can be traded, this paper

proposes a new P2P energy trading mode based on eBay C2C e-commerce model and GB power market design, in which "ElecBay" platform allows electric energy users to sign contracts and pay each other. The bidding process of users in ElecBay, and using game theory to carry out modeling and simulation; It proposed the use of prospect theory to analyze user behavior in P2P energy trading, and proposed an optimal response algorithm to find the game equilibrium point in [9].

The P2P distributed generation transaction model has been applied abroad, such as the US energy company LO3 Energy and the TranActiveGrid project based on the Ethereum blockchain startup ConsenSys. The project established the world's first energy market based on blockchain technology in a microgrid in Brooklyn, USA. Real-time access to data on power generation and electricity consumption through smart meters, and the use of blockchains to enable residents to successfully the surplus electricity generated from rooftop solar energy is sold to neighbors in a P2Pt manner. In addition, Austria's Grid Singularity hopes to combine the "energy market + data services" combination model to create a decentralized energy trading platform, while further utilizing the platform's transaction data to provide data analysis, smart grid management, investment trading decisions Suggest a series of value-added services.

### C. Decentralized transactive mechanism design

Considering the constraints of decentralization, real - time, incentive compatibility and convenient operation, a complete set of auditing, bidding, clearing and settlement mechanism is designed for P2P energy transaction between prosumers. The flow of distributed energy transaction is shown in Fig. 2 below, including requirements publishing, qualification auditing, transaction confirmation, transaction execution and transaction settlement

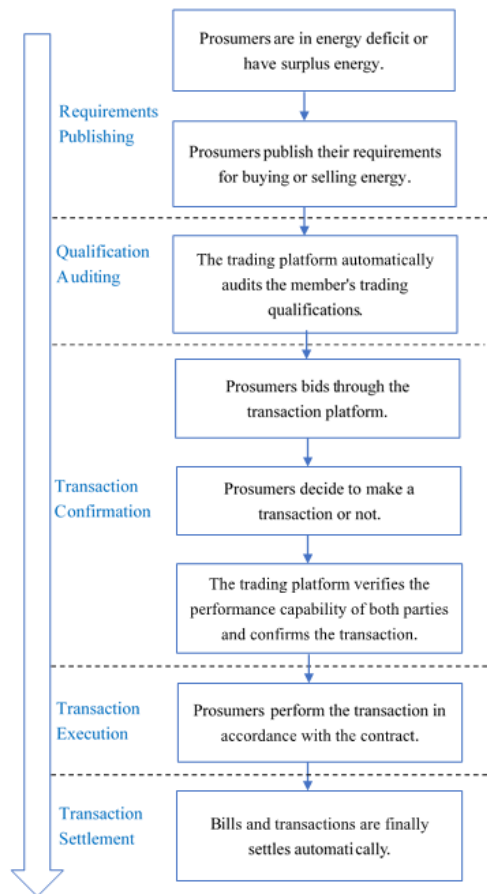


Fig. 2 Distributed energy transaction flow

### III. MECHANISM DESIGN BASED ON SMART CONTRACT

#### A. Blockchain technology and Ethereum smart contract

Blockchain is a distributed database that is maintained by the whole network and maintains all historical transaction data. Its time-stamp, asymmetric encryption, distributed consensus, flexible programming and other technologies make it decentralized, time traceable, autonomous, open, and information can't be falsified. Based on blockchain technology, Ethereum has established a Turing-complete programming environment. Through the development platform provided by Ethereum, developers can establish smart contracts of any kind and publish them on the Ethereum public network, test network or private network. Smart contracts are event-driven, dynamic, multi-recognized programs that run on the blockchain and automatically process assets based on pre-defined conditions. The biggest advantage of smart contracts is the use of program algorithms instead of artificial arbitration. Execution of the contract. In essence, the contract is also a program, but unlike traditional IT systems, smart contracts inherit the three characteristics of the blockchain: data transparency, not

tampering, permanent operation. Smart contracts based on blockchain technology can not only take advantage of the cost-effectiveness of smart contracts, but also avoid the interference of malicious behavior on the normal execution of contracts. The smart contract is written into the blockchain in a digital form. The characteristics of the blockchain technology ensure that the entire process of storage, reading and execution is transparent and traceable and cannot be tampered with. At the same time, a set of state machine systems is constructed by the consensus algorithm that comes with the blockchain, so that the smart contract can run efficiently [10]. Ethereum's decentralized and Turing-complete features provide a good support for the design of distributed generation trading mechanisms. This section designs smart contracts for distributed generation transactions as a core part of a distributed generation trading mechanism.

#### B. Smart contract for Distribute energy transaction

Smart contracts are established based on the transactive mechanism designed above. They include requirements publishing function, qualification auditing function, transaction confirmation function, transaction execution function and transaction settlement function.

(1) Requirements publishing function: Any prosumer can submit a power sale or purchase request and must pay a certain margin.

(2) Qualification auditing function: The check system will review the transaction status of the integrated members (whether there are unfinished transactions, etc.), historical transactions and default records.

(3) Transaction confirmation function: Participating in the transaction user to make a quotation, the user makes a decision through the main decision-making model decision, the system checks the performance ability of both parties, and confirms the transaction. Once confirmed, the contract containing information such as trading hours, transaction details, etc. will be automatically stored by both parties.

(4) Transaction execution function: Participating transaction users execute the transaction automatically according to the contract at the appointed time.

(5) Transaction settlement function: Once the transaction is executed, the user will automatically settle according to the contract.

### IV. CONCLUSION

With the participation of multi-agents such as distributed power sources in the market competition, how to effectively stimulate the enthusiasm of independent power generation of distributed power generation users and ensure their fairness, openness and rationality is one of the research priorities of promoting distributed power generation market-oriented transactions. In the context of transactive energy, a

decentralized distributed energy transaction mechanism based on blockchain smart contract is proposed in this paper. It realizes P2P energy trading among prosumers.

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